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(71)(72) Applicant and Inventor: BILLINGHAM, Nicholas, Donnelly [GB/GB]; Low Farm, Shipton Road, Stratford-Upon-Avon, Warwickshire (GB).

(74) Agent: ADKINS, Michael; Withers & Rogers, 4 Dyer's Buildings, Holborn, London EC1N 2JT (GB).

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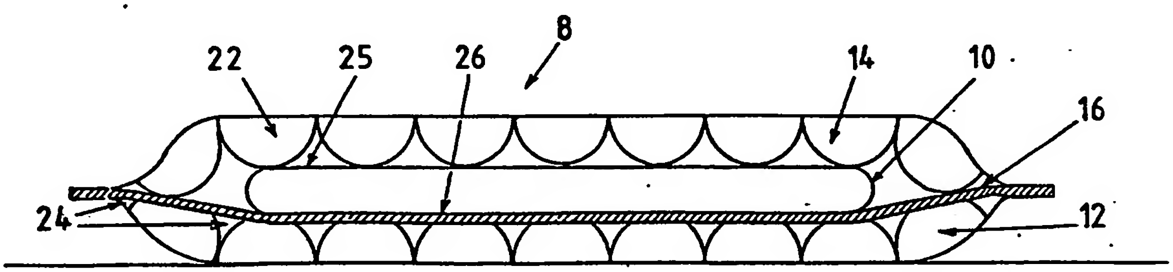

(57) Abstract

A solar heating mat which comprises a lower insulating member (12), an upper insulating member (14) and a removable inner tube (10). The upper insulating member (14) is transparent to solar radiation, and the tube (10) is absorbent of solar radiation. Inner tube (10) has an inlet connection (18) and outlet connection (20) so that a liquid e.g water can circulate through the tube and be heated.

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SOLAR HEATING MATS

This invention relates to solar heating mats, and in particular to lay-flat solar heating mats to heat large liquid, e.g. water, volumes.

Considerable attention has been given in recent years to the effective use of solar energy, and it has become apparent that different operating requirements may require different technical solutions. Thus the rigid solar panels, generally constructed as a box having a base along which a thin sheet of water flows, the upper face of the box being closed by a glass panel impinged by the sun's rays, have met widespread acceptance particularly for use as angled roof-mounted structures in order to provide large temperature rises in relatively small instantaneous volumes of water: - that is only a very small proportion of the total water volume to be heated in a panel at any one time. For large volume requirements, such as for heating a swimming pool, it is known to assemble a number (e.g. 20) of such solar panels together, and to mount them angled generally towards the sun on a specifically-constructed support; such an assembly is expensive to install, especially if a thicker glass is used to minimise the likelihood of breakage, and difficult to repair, perhaps requiring a complete panel to be replaced. Thus relatively few such assemblies, notwithstanding their effective use of the available ground area, have been installed, and where installed have been

found costly to maintain.

An alternative solution proposed has been the use of lay-flat mats, for installation on flat or slightly angled surfaces, (up to a slope of 1 in 40), such as specially-strengthened flat or slightly-angled flat-roofs, or more usually the ground. However such mats require a large ground area, and thus proposals such as that of GB 2 103 785 A to use a mat made of black pigmented hose pipes arranged side by side lengthwise and which do not therefore make efficient use of the available area, both because of the gaps between adjacent pipes and the curved surfaces presented to the incident radiation, have not found favour.

This disadvantage is compounded in the proposal disclosed in British Patent 1 525 935 which uses a single innertube to carry the liquid to be heated and a single outer tube surrounding the innertube, with a gap between the inner and outer tubes. Such tubing is expensive to manufacture and difficult to repair. Special webs need to be provided between the tubes to maintain the gap.

A modified proposal which in part avoids this difficulty is that of U.S. patent 4 404 958 which discloses using plastic sheets superimposed to delimit a tube for circulation of a gas to be heated by contact with radiant heat absorbing means in the collector. together with an insulating chamber communicating with the tube through at least one aperture; separate spacing means for the

insulation chamber is not needed with this arrangement as the heat transfer gas inflates both the tube and the insulation chamber. This interconnection reduces according to its inventor the likelihood of the collector being damaged through overheating upon deflation of the tube; but the mat is complicated in construction, expensive to manufacture, and difficult to repair. Some of the heated air in the tube can transfer from the collector to the insulating tube from whence its heat can be lost to atmosphere reducing the unit heat conversion efficiency.

A further arrangement is disclosed in US 4 203 425, again however using air as its heat transfer medium. This proposal has"a top member containing a plurality of transparent sealed air pockets allowing passage of radiant energy but preventing conductive and convective heat losses generated inside the collector". A central black-coated absorbent plastic member divides the centre of the collector into a plurality of interconnected inflatable upper and lower chambers connected to air pumps at one end for circulation of the air to be heated and to a constriction valve at the other. The lower end of the lower chamber consists of a cover containing a multiplicity of insulative sealed air channels. The ends of all the plastic sheets are heat sealed or bonded. This arrangement is also complicated in construction and to manufacture and difficult to repair. Because air is the medium to be heated, with its low specific heat capacity, relatively

large volumes need to be pumped through the unit which uses dual large-capacity pumps, so that this arrangement implies high operating costs.

It is an object of my invention to provide a solar unit which uses a liquid e.g. water, as the medium to be heated.

It is a further object of my invention to provide a solar mat in which the heat losses equal the heat absorption at a mat temperature below that at which the mat components suffer thermal injury, for instance should the circulating pumps fail or be inadvertently switched off.

It is yet a further object of my invention to provide a solar mat which can readily be repaired, specifically a solar mat in which the liquid-carrier is a removable and replaceable tube.

Thus according to the invention there is provided a solar heating mat comprising a first insulating member, a second insulating member transparent to radiant heat from the sun and connected to the first insulating member, and a tube positioned between the members, the tube having at least one surface absorbent to radiant heat from the sun, characterised in that the tube is removably positioned between the members and in that it has a water inlet connection and a water outlet connection.

My invention will be further described by way of example with reference to the accompanying drawings in which:

Fig. 1 is a plan view, partly section of a solar mat; and

Fig. 2 is a section along the line II-II of Fig. 1.

The mat 8 comprises an innertube 10, a lower insulating member 12, an upper insulating member 14, and a support member 16. The tube 10 has at opposite ends and inlet connection 18 and an outlet connection 20.

Innertube 10 is a flexible black polyethylene tube, preferably of the polyethylene known as high density grade and with an ultra-violet inhibitor, selected for its viscoelastic behaviour at varying temperatures; and for its long term recovery (preferably virtually 100%) from low stresses involving no more than 2% maximum strain, as may occur if the tube outlet becomes blocked or crimped. (as from a heavy weight such as a vehicle wheel on the outlet tube) whilst the pump is running, i.e. before for instance the weight is removed or before the pump is automatically switched off by a water or pump-outlet pressure sensor. As is also well known to those experienced in selecting suitable grades of material, polyethylene yield stress is highly dependent on density (that is the degree of crystallinity, increasing rapidly with density; with temperature, the yield strain increases steadily with temperature, being between 10% and 20% at 20°C, whereas the yield stress falls with increasing temperature.

I suggest that to avoid premature failure of inner-tube 10 before the yield point, it is important wherever possible to avoid a low molecular weight polymer with a high melt flow index, very rapid loading approaching explosive rates at the normal ambient air temperatures, long loading periods particularly at higher temperatures, and subjecting the tube to very low temperatures, and my system will be designed with these considerations in mind.

It is also important for tube 10 not to engage sharp notches, corners or rough edges. The lower insulating member 12 provides mechanical protection, as well as having encapsulated air bubbles 22 for insulation. Since a typical mat according to my invention can have a length of 10 metres and a width of 1.5 metres, the weight of water in tube 10 may be 750 kilos which has the advantage of being sufficient in itself to hold the mat down under normal wind conditions but the potential disadvantage of heavily stressing the air bubbles 22 in lower insulating member 12 and tending to force the contained air to permeate steadily out from these bubbles. Thus I prefer a barrier-sealed air bubble cushioning material with a bubble height of 12.7mm, such as that supplied under the Registered Trade Mark "Air Cap" by Sealed Air International, and intended to provide long-term air retention in the individual bubbles, and of a sufficient pillar height not to be squashed flat by the water weight. The bubbles 22 in the commercially supplied material are formed generally as cylindrical columns, with gaps 24 therebetween into which the respective adjacent portions of the lower surface 26 of the tube 10 would be forced by the weight of the contained water, with possible stressing and premature rupture of the tube, leading to water leakage. Such leakage in the short term would reduce the thermal efficiency of the solar mat 8 and in the longer term if all the water to be circulated leaked, to burning-out

of the water-circulating pump (not shown). Furthermore, and particularly for temporary installations to which the mat 8 is transported rolled and there unrolled onto ground more or less suitably prepared, one or more of the bubbles may be punctured as by a stone or the like, again providing an unsupported area into which the adjacent portion of tube 10 can sag and stretch and potentially rupture. Thus I provide the support member 16, to spread the loading from tube 10 and preferably also to permit additional insulation against heat loss from the water in tube 10 to ground. The support member 16 is conveniently of lightweight foam, preferably selected from the group designed to protect against scratching, marking and abrasion upon relative movements between the lower surface 26 of tube 10 and this support member 16. A suitable material is that sold under the Registered Trade Mark "Cell Aire", again by Sealed Air Ltd., being of polyethylene, and usefully having a thickness of 3.00mm and density 25 kilograms per cubic metre; though a different thickness and density can be used depending on the weighting from tube 10 and the cell structure or composition or material of lower insulating member 12.

For many applications it will be convenient to select for upper insulating member 14 the same material as that used for lower insulating member 12. Even though

upper insulating member 14 is not required to carry the weight of water in tube 10, nevertheless unless otherwise protected the upper insulating member 14 may be jumped upon by dogs or cats, and one or more of the individual encapsulated air bubbles thereby punctured so that a material having a larger number of smaller height and smaller diameter bubbles may be preferred. Furthermore, because upper insulating member 12 is not required to carry the weight of the water in tube 10, in an alternative embodiment the bubbles may retain their contained air for an adequate period without being of the barrier sealed type. If upper insulating member 14 is of different visual appearance, as by having more but smaller bubbles, the mat 8 is less likely to be positioned upside down by a non-professional installer. The material for upper insulating member 14 will however be selected to permit the passage of the incident solar radiation therethrough.

It is an important feature of my invention that whilst preferably lower insulating member 12, upper insulat-member 14 and support member 16 are formed as a unitary assembly, tube 10 is removably positioned between member 12 and 14 (specifically between members 14 and 16) and is not connected thereto. Thus should tube 10 rupture, it can be removed and replaced. To permit this, normally I will provide a releasable connection at the ends 30,32 of mat 8; to replace a tube 10, the existing

tube will be withdrawn from one end e.g. end 30, after having emptied the tube of water and after having connected the replacement tube to that end of the existing tube adjacent end 32, so that the replacement tube is drawn in simultaneously with removal of the existing tube. Any convenient releasable connection can be provided, including clips, staples or the zip-type connection increasingly being used for resealable polyethylene bags. In an alternative embodiment, I provide for removal of the tube laterally through one or other of the long sides 34, 36 of the mat, and in this embodiment it will often be more convenient to insert the replacement tube separately i.e. without coupling it to the tube being replaced.

The unitary assembly of members 12, 14, 16 other than at the locations of the releasable connection, can conveniently be joined as by heat welding the respective edges together, and the materials for members 12,14,16 will be selected with this requirement in mind. It is partly for this reason that I have above specified polyethylene for each of these members, though other suitable materials will be readily apparent to those knowledgeable regarding the published properties including the optical and mechanical properties of film-like materials, to select suitable materials to be used for all three members or in combination with one or other of the polyethylene members.

Whilst the energy conversion efficiency of my mat may not be as high as for certain designs of solar panel, my mat is of low cost,readily available materials, light in its self-weight, rollable for ready storage and transport, and simple to install.

It will be understood that for locations where the water weight of a filled mat may not itself by adequate to maintain the mat grounded, separate hold-down means may be used, including extending the ends 30,32 and/or sides 34,36 to permit restraining grommets to be applied.

Inlet connection 18 and outlet connection 20 can be provided by pipes sealingly received at the respective ends of tube 10, the ends of these pipes remote from tube 10 having couplings for connection to the water pump and heated-water receiver respectively.

In use, the mat 8 is placed so that the incident solar radiation impinges upon upper insulating member 14, and passes therethrough so as to be absorbed by the inner tube 10 of flexible black polyethylene tube. An advantage of using a tube 10 is that radiation passing through rather than being absorbed by the upper surface 25 is likely to be absorbed by the lower surface 26; it is advantageous if the support member 16 in addition to its other properties as specified above is also reflective so that any radiation emerging from lower surface 26 is reflected back towards surfaces 26 and 25 for possible

absorption. Tube 10 contains water, conveniently to a depth of 2", sufficient to fill the tube and to distend it fully without over-stretching the polyethylene, gently flowing from inlet connection 18 to outlet connection 20 and absorbing heat from surfaces 25 and 26. Usefully the water flow rate will be 10 litres/minute/m^2 and in a prototype test on a 6 sq. metre mat the water temperature difference between inlet and outlet was 8^oC representing an incident radiation energy conversion efficiency of 62%. The area of the mat can of course be selected according to the total volume of water to be heated, and to the intensity of the anticipated solar radiation.

It is another important feature of my invention that the materials selected permit some re-radiation, increasing with increasing temperature difference between the ambient temperature and that of and in mat 8. In my prototype as above, this temperature stabilised at 75^oC, well within the serviceable range of the materials selected; should the pump fail or be inadvertently switched off or if there be a power failure, the mat will not melt down if so "temperature-stabilised", so avoiding the need subsequently to replace it and any consequential damage should the mat for instance be located on the roof of a building into which the entire store of water might eventually leak should the mat deterioration not be observed.

The operation of my water pump can be controlled in response to water-temperature or water-pressure sensors in the mat, or in response to water-flow sensors at inlet connection 18 or outlet connection 20.

In an alternative embodiment, the lower insulating member and the support member 16 can be combined, either as a single composite support with different respective sizes and shapes of entrained bubble; or as a single layer, in which case the bubble size will conveniently be small, preferably similar in size to that of the cellular foam bubbles of support member 16, and in one embodiment a support member 16 having a thickness equal to the combined thickness of members 12 and 16 as seen in Fig. 1 can be used.

To warn against water leakage from inner tube 8, suitable sensing means can be used. One such means is a chemical which changes colour in the presence of water; alternatively a water presence sensor can be embedded in the upper lay of support member 16 below inner tube 10 - the electrical wiring to the sensor (and to any electrical or electronic temperature sensor used) will be "taped" to prevent damage to inner tube 10 upon its insertion or removal from the envelope.

CLAIMS

1. A solar heating mat comprising a first insulating member, a second insulating member transparent to radiant heat from the sun and connected to the first insulating member, and a tube positioned between the members, the tube having at least one surface absorbent to radiant heat from the sun, characterised in that the tube (10) is removably positioned between the members (12,14) and in that it has a water inlet connection (18) and a water outlet connection (20).

2. A solar heating mat according to Claim 1 characterised in that the second insulating member (14) and the tube (10) can re-radiate absorbed solar energy, the amount of re-radiation being dependent upon the temperature difference of the mat above ambient so that the mat can become temperature stabilised, the said stable temperature being below the melting point of the members and of the tube.

3. A solar heating mat according to Claim 1 characterised in that the tube is of flexible black polyethylene of high-density grade, and including an ultra-violet inhibitor, selected from the group having visco-elastic behaviour over a range of temperatures and for its ability recover from the stress of an applied 2% strain.

4. A solar heating mat according to Claim 1 characterised in that the first insulating member (12) comprises encapsulated air bubles (22).

5. A solar heating mat according to Claim 4 in which the encapsulated air bubles (22) are barrier - sealed to inhibit loss of the contained air.

6. A solar heating mat according to Claim 5 characterised in that the encapsulated air bubbles (22) are formed as cylindrical columns.

7. A solar heating mat according to Claim 1 characterised in that a support member (16) is positioned between the tube (10) and the first insulating member.

8. A solar heating mat according to Claim 7 characterised in that the support member (16) is of light-weight foamed material, selected from the group having limited tendency to scratch or abrade the tube (10) upon relative movement between the tube (10) and support member (16).

9. A solar heating mat according to Claim 7 characterised in that the support member (16) is of polyethylene reflective of the impinging radiant heat from the sun.

10. A solar heating mat according to Claim 1 characterised in that the first and second members comprise a plurality of independent air cells, the cells of one member being visually distinct from those of the second member so that in use the mat can clearly be positioned with the second member uppermost i.e. nearest the sun.

11. A solar heating mat according to Claim 1 characterised in that the members are connected by heat welding.

12. A method of using a solar heating mat as Claimed in claim 1 characterised in connecting the water inlet connection (18) to the outlet of a pump and the water outlet connection (20) to the inlet of a pump, and providing heat exchange between the water outlet connection (20) and the said inlet of a pump.

13. A method of re-assembling or of repairing a solar heating mat as claimed in Claim 1 and having a removable tube characterised in joining one connection (18,20) of the tube to the opposed connection of another tube, and drawing the tube out from between the member by the other of the connectors, whilst simultaneously drawing in the said another tube between the said members.

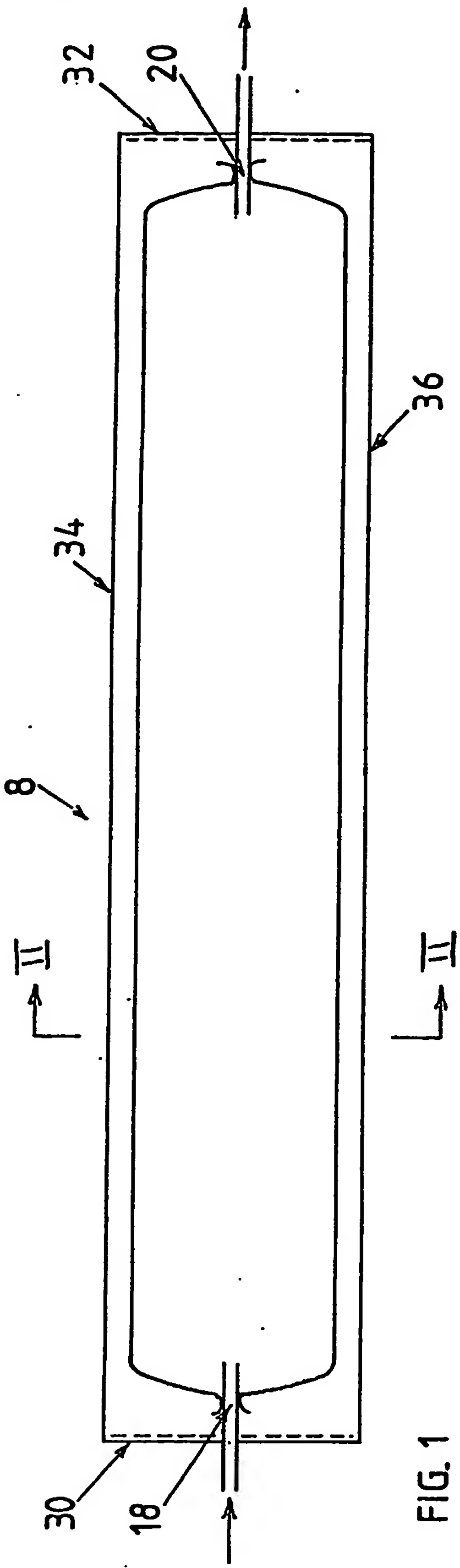

FIG. 1

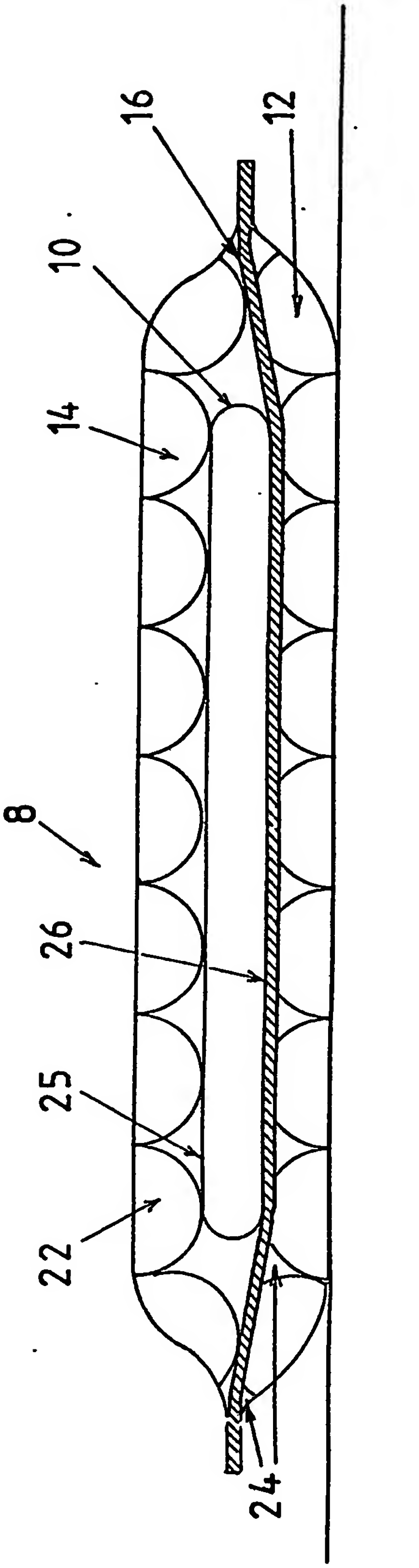

FIG. 2

SUBSTITUTE SHEET

INTERNATIONAL SEARCH REPORT

International Application No PCT/GB 86/00363

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [6]

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC^4: F 24 J 2/24

II. FIELDS SEARCHED

Minimum Documentation Searched [7]

Classification System	Classification Symbols
IPC^4	F 24 J

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [8]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [9]

Category [*]	Citation of Document, [11] with indication, where appropriate, of the relevant passages [12]	Relevant to Claim No. [13]
X	EP, A, 0070757 (CENTRE NATIONAL D'ETUDES SPATIALES) 26 January 1983 see abstract; page 2, lines 23-33; page 3, lines 1-19 and 29-31; page 4, lines 5-19; claims 1-3; figure --	1
X	DE, A, 2851793 (LUBOCHIK) 12 June 1980 see claims 1,4,9,10; page 3, lines 28-30; page 4, lines 1-13 and 23-27 and 34-38; figures 1-4	1,4,11
Y	--	2,5,6,7,10, 12,13
Y	US, A, 4217885 (BOWLES) 19 August 1980 see column 2, lines 48-65; column 5, lines 5-30; figure 1 --	2,12
Y	GB, A, 2025602 (TAYLOR) 23 January 1980 see abstract; page 1, lines 58-79 and 102-114; page 2, lines 4-24 and 35-40; figures 2 and 3 --	5,6,10 ./.

* Special categories of cited documents: [10]

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IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
2nd October 1986	31 OCT 1986
International Searching Authority	**Signature of Authorized Officer**
EUROPEAN PATENT OFFICE	M. VAN MOL

III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)

Category *	Citation of Document, with indication, where appropriate, of the relevant passages	Relevant to Claim No
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Y	EP, A, 0052321 (METZELER KAUTSCHUK) 26 May 1982 see page 5, lines 33-38; figure 3	13
A	FR, A, 2280867 (KLEINWACHTER) 27 February 1976 see page 1, lines 38-39; page 2, lines 1-35; claims 1,2; figure 1	3,9
A	DE, A, 2700714 (BOETTCHER) 13 July 1978 see claims 3 and 4; page 2, lines 1-15; page 3, lines 6-23; figures 1-4	1,2
A	FR, A, 2438243 (SHELL) 30 April 1980 see figures 1-3	1

ANNEX TO THE INTERNATIONAL SEARCH REPORT ON

INTERNATIONAL APPLICATION NO. PCT/GB 86/00363 (SA 13773)

This Annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report. The members are as contained in the European Patent Office EDP file on 13/10/86

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